

**Perspectives on
Advanced Learning Technologies and Learning Networks and Future
Aerospace Workforce Environments**

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INTRODUCTION

The engineering profession resonates with rhetoric about the needs for radical restructuring of engineering education and training, and the opportunities for enhancing learning through the use of new technologies. But while the volume of the standard rhetoric accurately reflects an urgently growing sense that learning in the new millennium should be radically different, its content seldom reflects strategies and detailed, practical plans for effecting that change. Current research and development activities in learning technologies are characterized by being, a) fragmented and disparate, and b) mostly concentrated on near-term product development.

Attempts have been made to remedy these problems - for example, NSF sponsored Engineering Education Coalitions, and the Learning Federation is developing a research agenda for learning technologies designed to have the greatest impact on post-secondary and life-long learning in science and technology. However, to date, they have not made a significant impact on engineering workforce training.

To set the stage for succeeding presentations, an overview of the advanced learning technologies is given in this presentation along with a brief description of their impact on future aerospace workforce development. The presentation is divided into five parts (see Figure 1). In the first part, a brief historical account of the evolution of learning technologies is given. The second part describes the current learning activities. The third part describes some of the future aerospace systems, as examples of high-tech engineering systems, and lists their enabling technologies. The fourth part focuses on future aerospace research, learning and design environments. The fifth part lists the objectives of the workshop and some of the sources of information on learning technologies and learning networks.

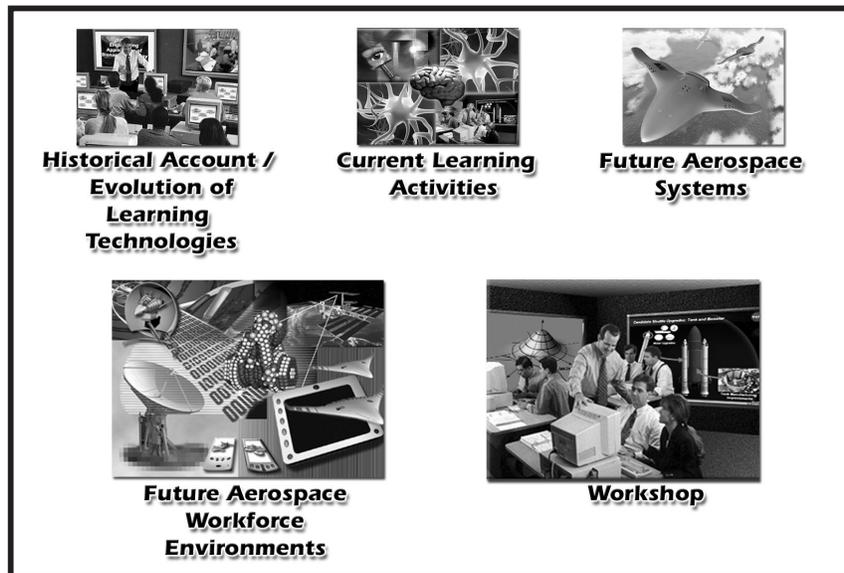


Figure 1

EVOLUTION OF LEARNING TECHNOLOGIES

Computer-based learning technology dates back to the 1960s (see Figure 2). Passive computer-based instruction systems were built in the 1960s and 1970s. Later developments in that period included learner modeling and more elaborate computer-learner interfaces.

The addition of expert systems to computer-based instruction resulted in the Intelligent Tutoring Systems (ITS) of the 1970s and 1980s. These systems had explicit models of tutoring and domain knowledge, and were more flexible in their response than computer-based instruction. The advent of intelligent agents, which enabled the learner to manipulate cognitive artifacts from several perspectives or viewpoints, led to the Interactive Learning (IL) systems of the 1990s. In the late 1990s, a move towards Collaborative Distributed Learning (CDL), with distributed resources, occurred. Current trend is towards using Learning Networks (LN), for enhancing the effectiveness, access and affordability of learning. In learning networks extensive use is made of intelligent agents, learning is guided by cognitive systems, and the learner is an active and reflective participant in the learning process.

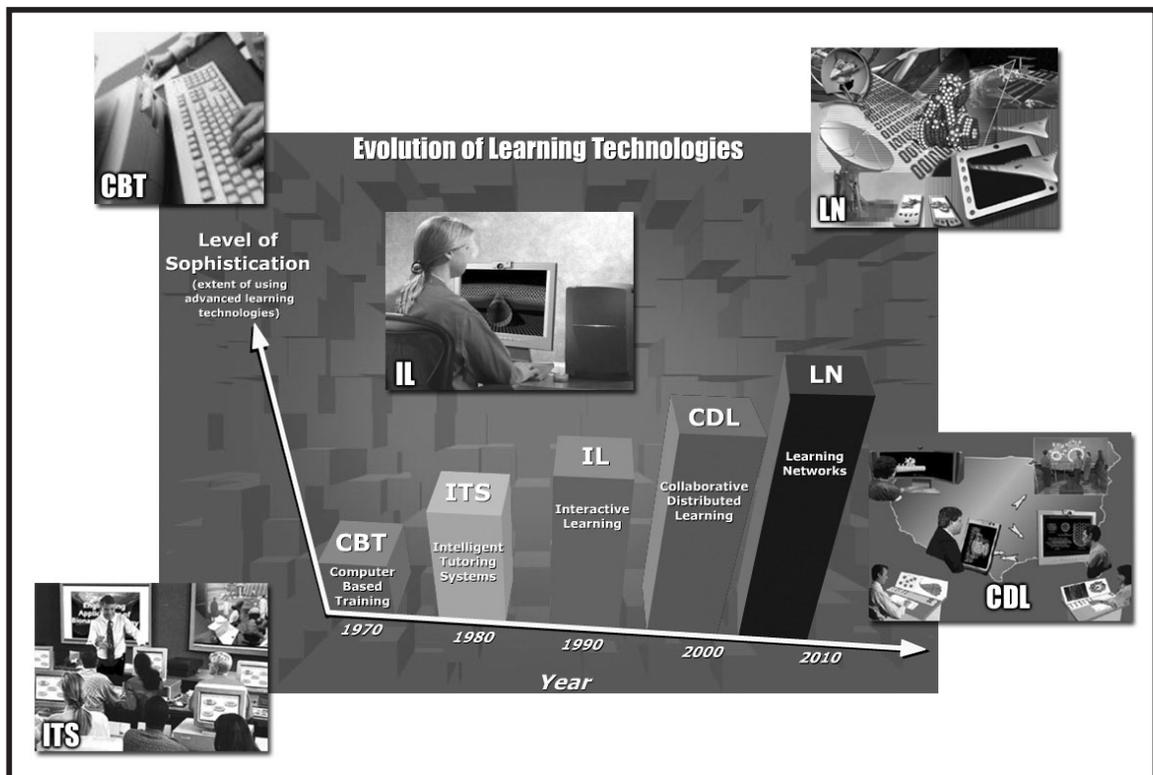


Figure 2

EDUCATION, TRAINING AND LEARNING

There has long been a philosophical gap between education and training. The goal of education was to impart high-level cognitive skills that would underpin lifelong learning. The goal of training was to bring performance up to a level that would let people successfully achieve tasks. Recently, however, training began to emphasize the skills involved in lifelong learning, as evidenced by continual-growth workshops and online training facilities on the Internet. In a sense, both education and training objectives fit in the larger classification of learning objectives (Figure 3).

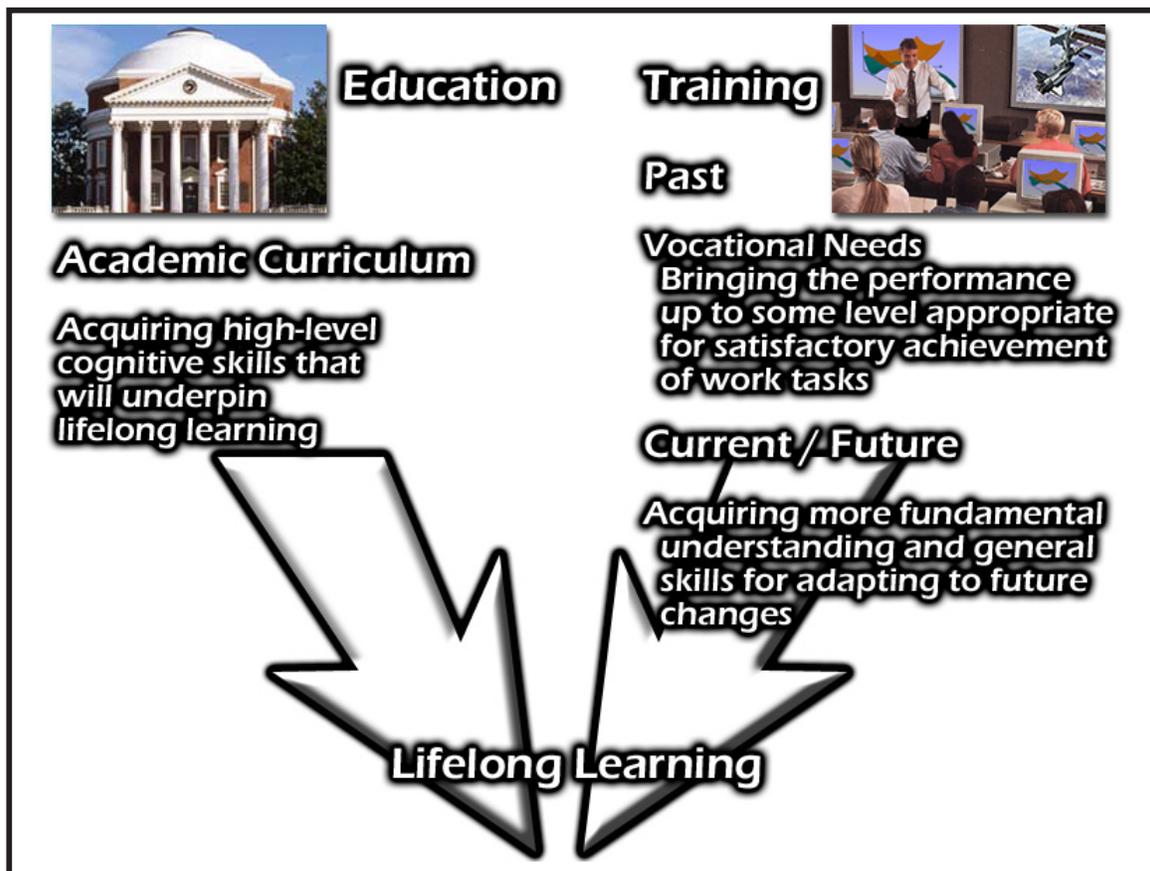


Figure 3

LEARNING OBJECTIVES, INSTRUCTIONAL MODELS AND TECHNOLOGIES

The desired outcome of learning can range from information transfer to skill and knowledge acquisition to the more ambitious goal of development of critical thinking and creativity skills. The instructional model and method used for accomplishing these goals vary from instructor-centered, learner-centered to learning-team centered. In the learner-centered model, the learner is at the center of the learning process, and calls on many information sources. Learning-team center models include virtual classrooms and web-based distance learning models. The technologies employed in the three models are distribution, interactive and collaborative technologies, respectively (see Figure 4).

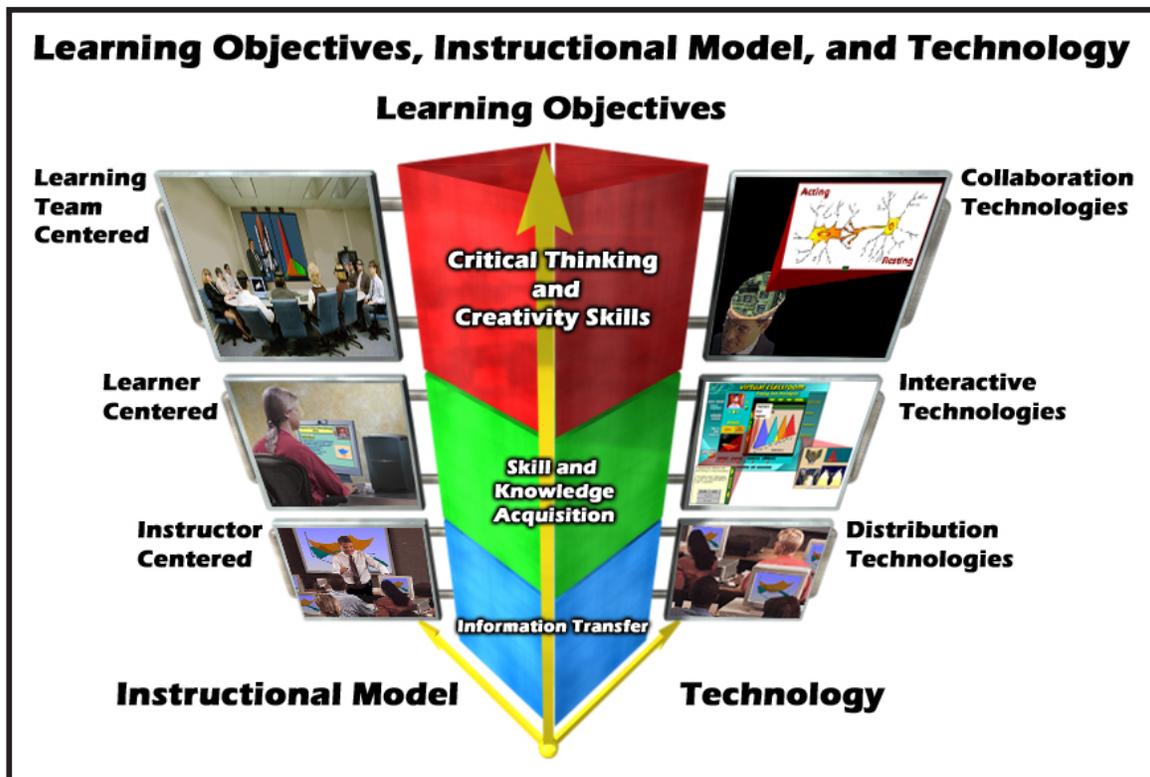


Figure 4

LEARNING NETWORKS

The convergence of computing, communication and information technologies is providing opportunities for creating effective environments for life-long learning through expanding the concept of a university which is, typically limited to a campus, to that of a learning network (Figure 5). In such a network, the classrooms are augmented by e-learning facilities (e.g., virtual classrooms); the libraries are expanded into intelligent knowledge repositories (with digital libraries and intelligent search and information visualization capabilities); the physical test and experimental facilities are augmented with access to more elaborate facilities at government labs, along with computer simulation of these facilities; and Immersive telepresence technology is used to provide interaction with geographically dispersed instructors and learners at other locations.



Figure 5

ACTIVITIES OF LEARNING NETWORKS

The learning networks can significantly enhance the effectiveness of engineering education, by changing the way three of the major functions of a university are carried out, namely, development of content for courses, packaging courses into curricula and programs, and delivery of these programs to learners (Figure 6).

Each course is divided into self-contained learning modules, and a consortium is established for generating the best content for each of the learning modules. Advanced instructional technology; modeling, simulation and visualization facilities and authoring tools are used in the development of the modules.

The learning modules are then packaged into disciplinary and interdisciplinary courses and training programs to satisfy the needs of diverse groups.

The packaged modules are presented to individuals as well as groups of learners. Collaboration and interaction is made available at many levels, both synchronously and asynchronously.

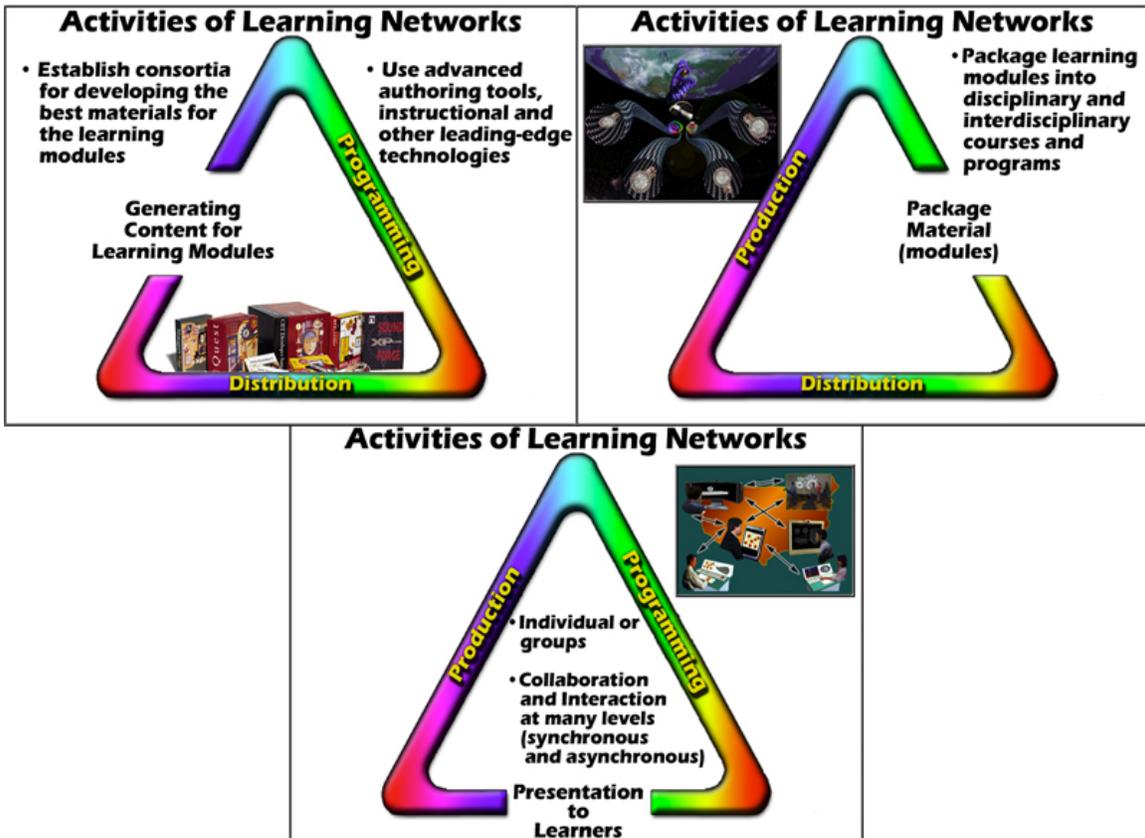


Figure 6

ADVANCED LEARNING ENVIRONMENTS

In order to meet the life-long learning demands of the future and broaden the awareness among the researchers and engineers in high-tech areas, three categories of learning environments are needed; namely, expert-led group learning environment; self-paced individual learning environment; and collaborative learning environment (Figure 7). The three environments, in combination, can reduce the time and cost of learning, as well as sustain and increase worker competencies in high tech organizations.

The human instructors in these environments will serve many roles, including inspiring, motivating, observing, evaluating, and steering the learners, both individually and in distributed teams.



Figure 7

EXPERT-LED LEARNING ENVIRONMENT

The human instructors in expert-led distributed learning in a virtual environment serve as coaches, guides, facilitators, and course managers. Their presentations focus on a broad overview of the topic and its diverse applications (Figure 8), and end with more penetrating, what-if questions that can enhance the critical thinking and creativity of the learners. Elaborate visualization and multimedia facilities are used in the presentations. Routine instructional and training tasks are relegated to the self-paced individual learning environment.

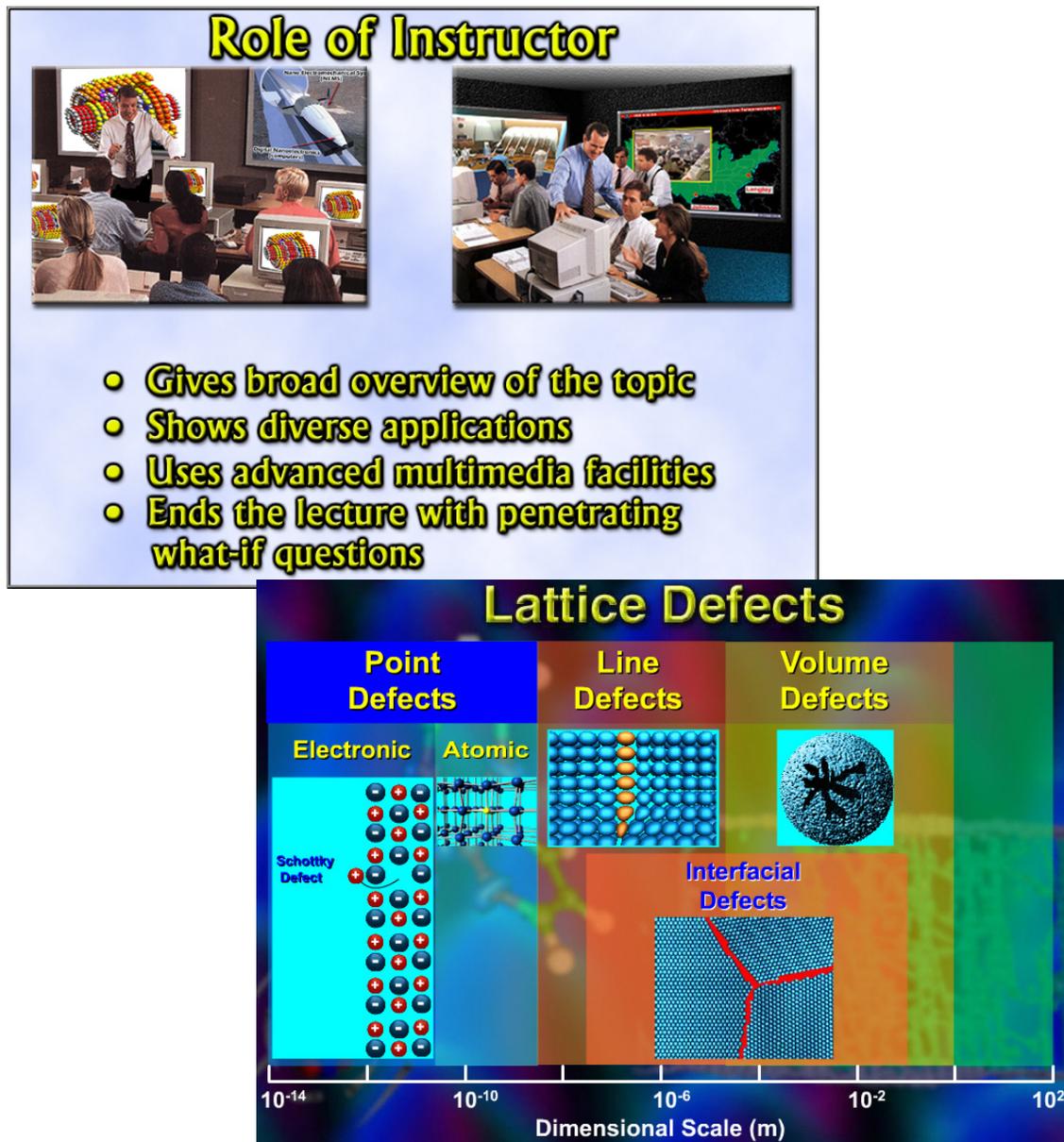


Figure 8

SELF-PACED LEARNING ENVIRONMENT

The individual learning environment engages the learner and provides a high degree of tailored interactivity. It can be used for self-paced instruction of routine material not covered in the lecture. Using virtual instructors assigned by the human instructors can enhance such instruction. It can be used to study the physical phenomena occurring at different length scales using advanced visualization, multimedia and multisensory immersive facilities. The individual learning environment can serve to carry out numerical and virtual experiments - computer simulation of physical experiments (Figure 9).



Figure 9

SELF-PACED LEARNING ENVIRONMENT

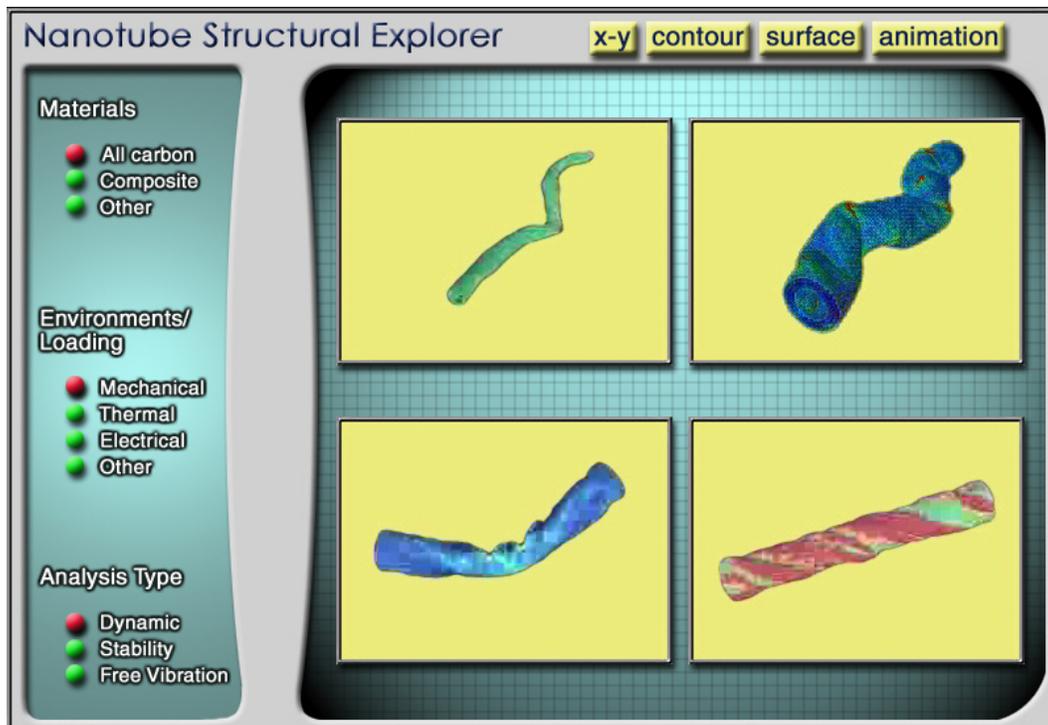
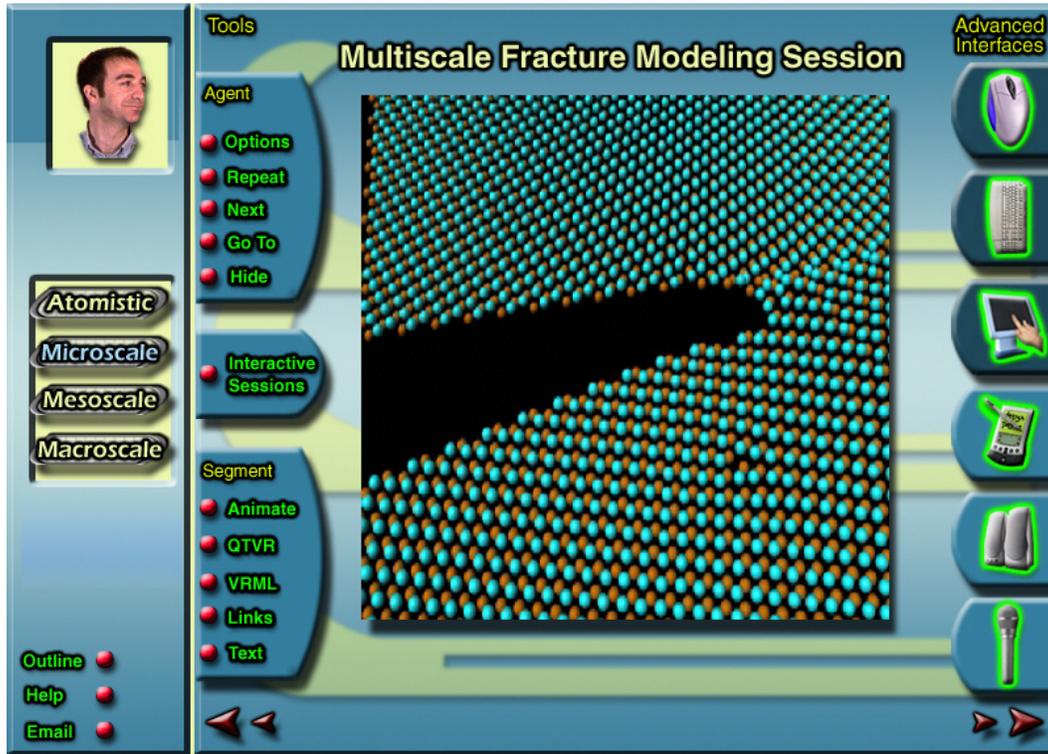


Figure 9 (continued)

COLLABORATIVE / DISTRIBUTED LEARNING ENVIRONMENT

Collaborative learning environments teach teamwork and group problem solving. Instructors and learners can be geographically dispersed. Eventually, they can be brought together through immersive telepresence facilities to share their experiences in highly heterogeneous environments involving different computing platforms, software, and other facilities, and they will be able to work together to design complex engineering systems beyond what is traditionally done in academic settings. Because participants can be virtually co-located without leaving their industry and government laboratories, collaborative learning environments can enable the formation of learning networks linking universities, industry and government labs. The ultimate goal of these learning facilities is to create an intellectual environment where academic and experiential learning are effectively and efficiently co-mingled. In such an environment, academic rigor is learned in concert with professional job performance, and academic complexities are addressed within the industrial concern (Figure 10).

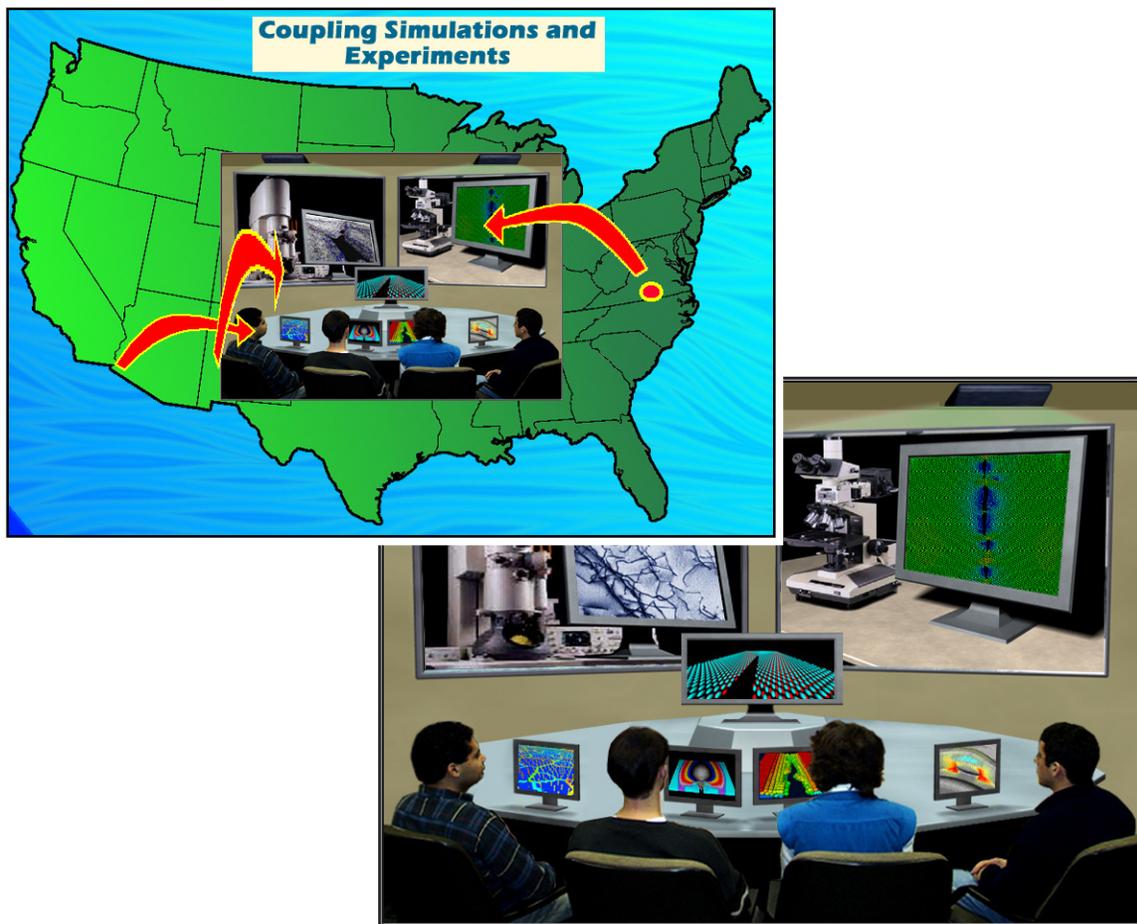


Figure 10

COLLABORATIVE / DISTRIBUTED LEARNING ENVIRONMENT

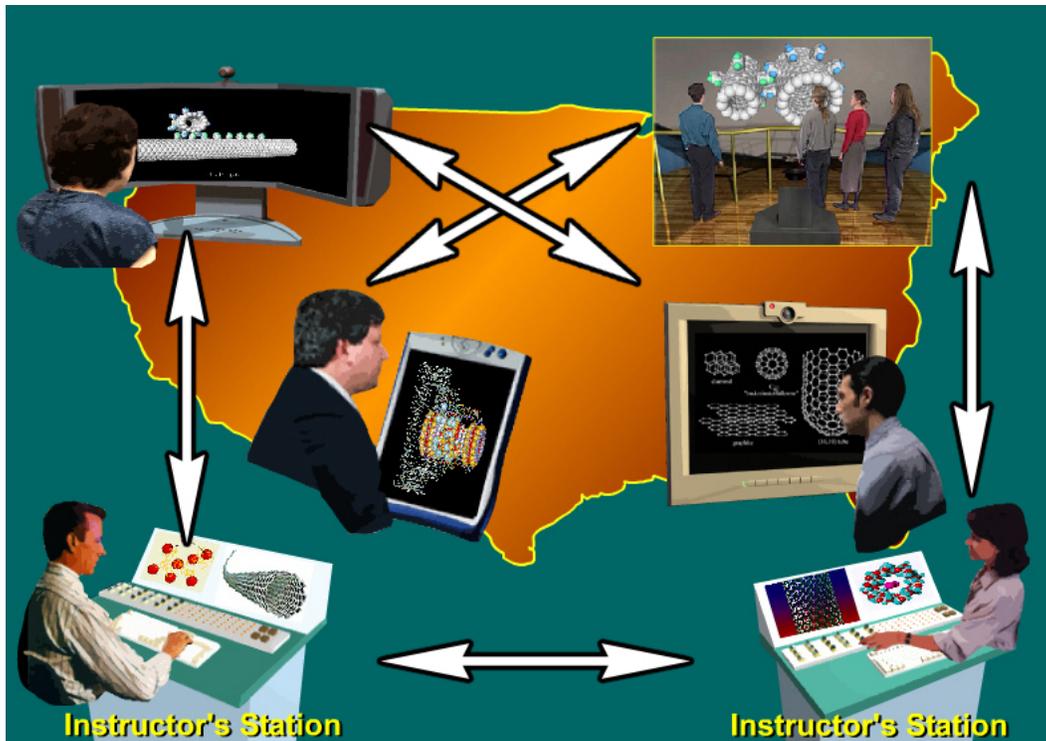
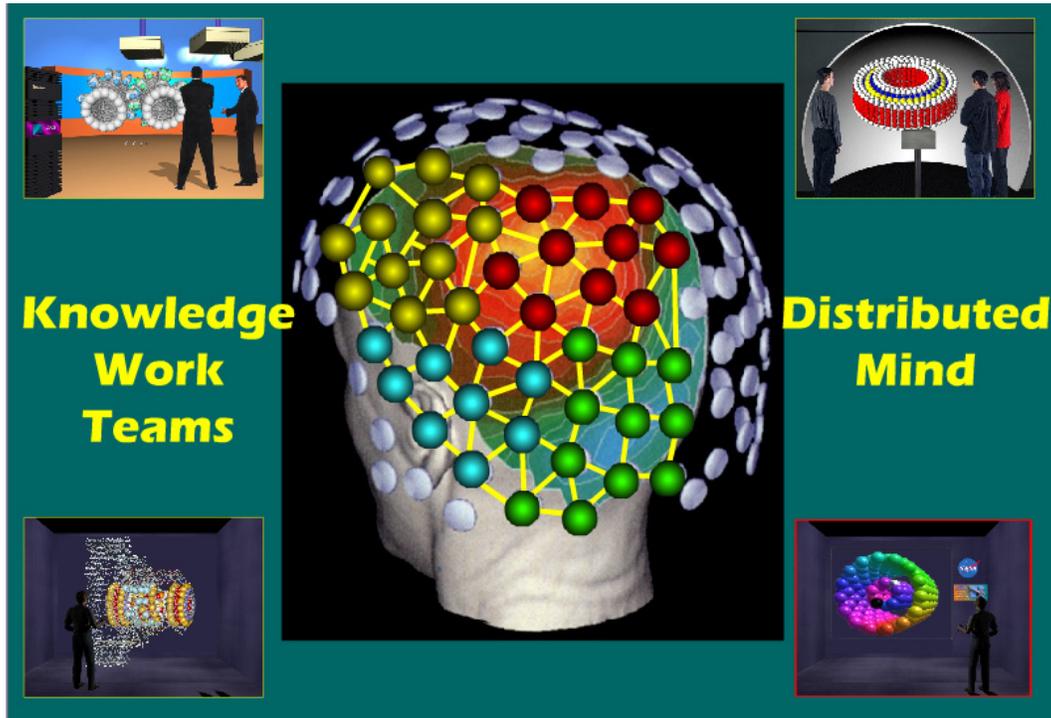


Figure 10 (continued)

SPECTRUM OF LEARNING ACTIVITIES

The various learning activities can be grouped into three categories: learning science; learning technologies, infrastructure and tools and; learning systems (Figure 11). The first category include human cognition/cognitive learning and thinking processes; learning strategies, mechanisms and approaches; models of instructor/learner interaction; knowledge representation and; evaluation, assessment and measurement issues in learning, and monitoring of learner behavior. The second category cover advanced simulation and interrogative visualization facilities; multimodal and adaptive interfaces; tools that support active engagement in tasks, collaborative and reflective processes; intelligent and mobile agents to provide help, motivation and move scenarios forward and; knowledge management, assessment and evaluation tools. The technologies and facilities can be integrated into the three learning environments: expert managed, self-paced and collaborative. The third category include e-learning systems and learning networks.

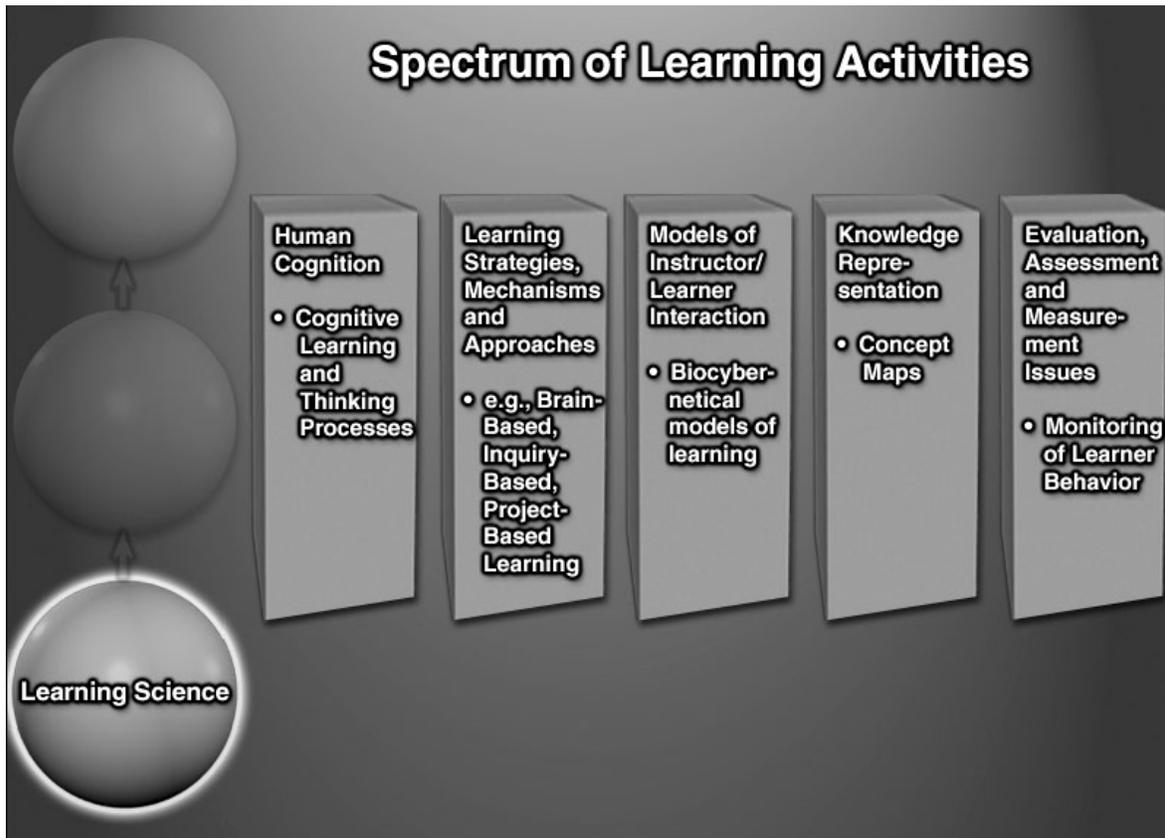


Figure 11a

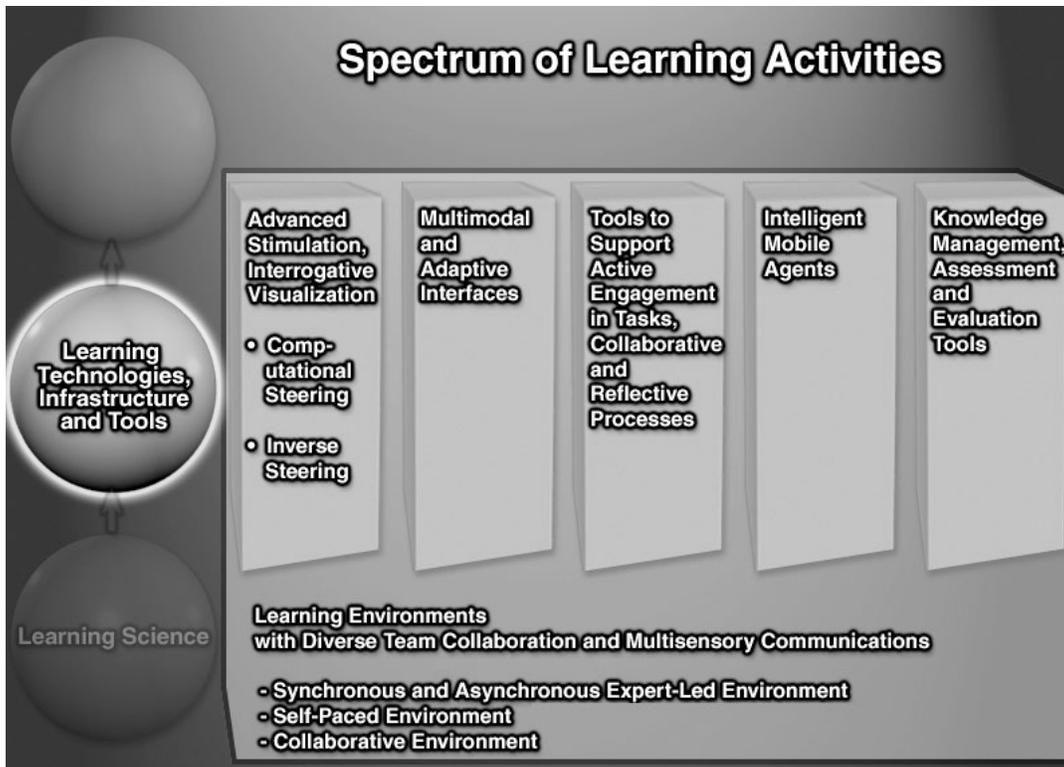


Figure 11b

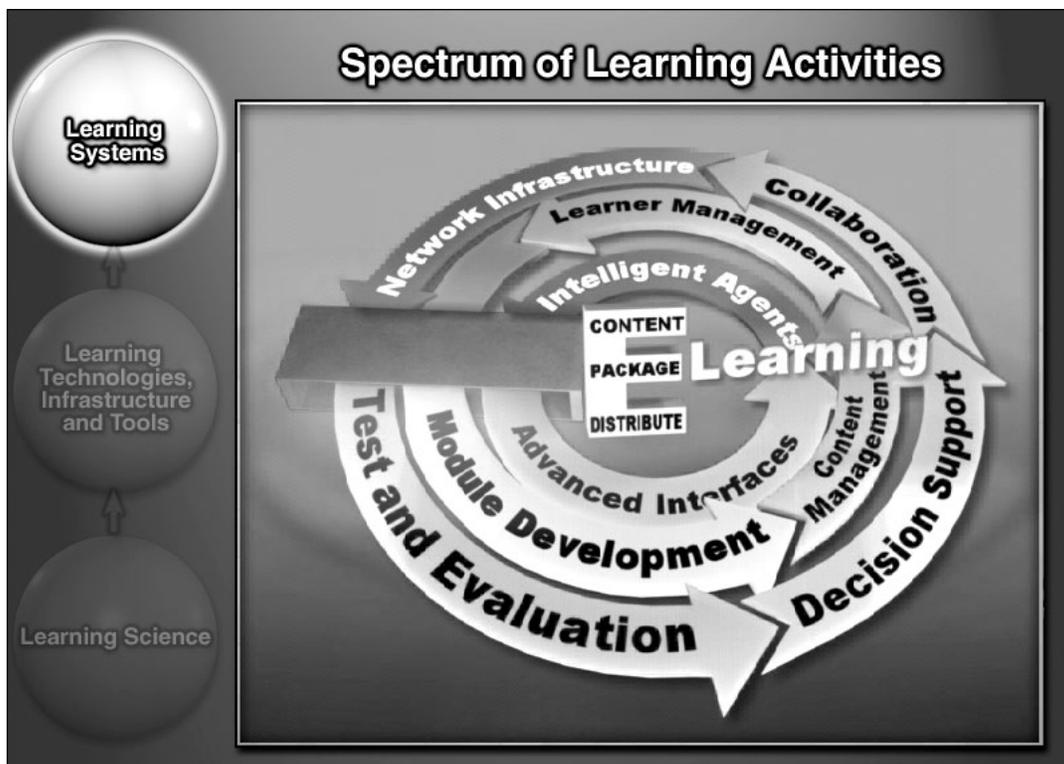


Figure 11c

RELEVANT TECHNOLOGIES

The development of advanced learning systems and learning networks require the synergistic coupling of a number of enabling and leading-edge technologies. These include (Figure 12): novel computing technologies/paradigms; high-capacity communication/networking; human/computer/network interfaces; instructional; information/knowledge; intelligent software agents; modeling, simulation and visualization; cognitive systems and; human performance.

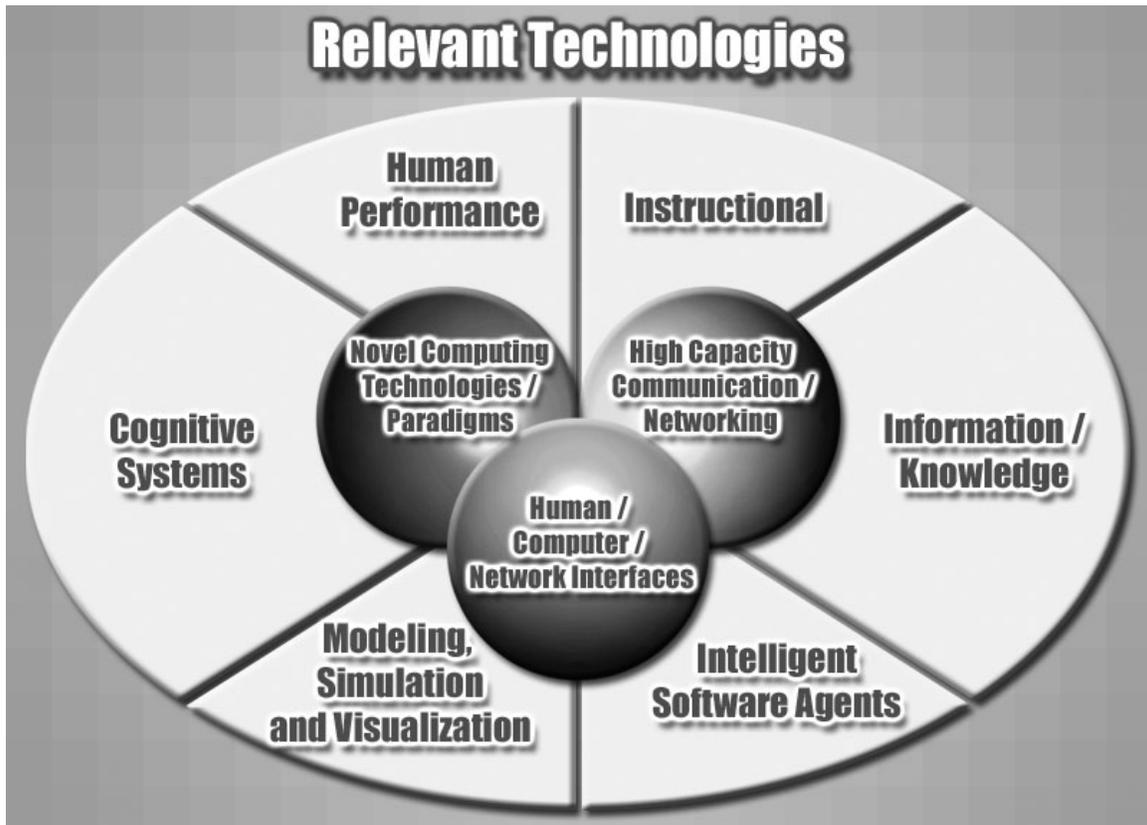


Figure 12

GOVERNMENT AND NON-GOVERNMENT ACTIVITIES

A number of government and non-government activities in the areas of advanced learning technologies and learning environments are currently underway. The government activities include (Figure 13): Advanced Distributed Learning (ADL) of DoD/OSTP; Adaptive Learning Systems of NIST; NSF Engineering Coalitions; e-Learning of the Department of Education and; Distance Learning of FGDL.

The non-government activities include MERLOT, FSRI's Advanced Learning Environments; University of Mississippi's Geospatial Information Coursework Development; MIT Open/Courseware Project; American Society for Training and Development (ASTD); United State Distance Learning Association (USDLA); Aviation Industry CBT Committee (AICC); and, The Training Place.

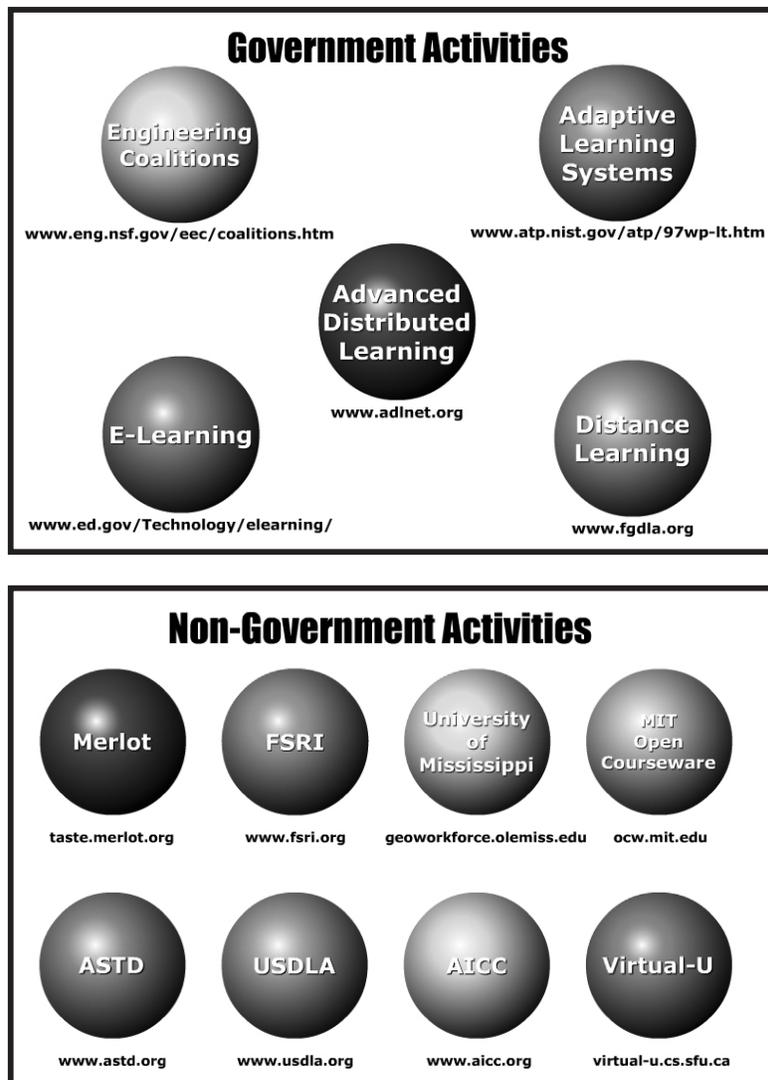


Figure 13

LEARNING TECHNOLOGY VENDORS

A list of some of the learning technology vendors is given in Figure 14. These include WBT, Mentorware, Pathlore, Avilar, Elluminate, and the Training Place.



Figure 14

TECHNICAL STANDARDS

Faced with a multiplicity of learning applications on the web, various initiatives can be found defining sets of metadata for describing them. It is of critical importance for the instructors and learners to find the learning materials when needed. This prompted a number of organizations to develop accredited technical standards, specifications, recommended practices and guides for learning technology. These include (Figure 15), the Sharable Content Object Reference Model (SCORM) of ADL; IEEE Learning Object Metadata (LOM) Standard and; the Learning Technology Standards of the Center for Educational Technology Interoperability Standards.



Figure 15

KEY COMPONENTS OF ADVANCED MODELING AND SIMULATION ENVIRONMENT

The realization of the strategic value of modeling and simulation in learning systems requires an environment that links diverse teams of scientists, engineers and technologists. The essential components of the environment can be grouped into three categories: intelligent tools and facilities, nontraditional methods, and advanced interfaces (Figure 16). The three categories are described subsequently.

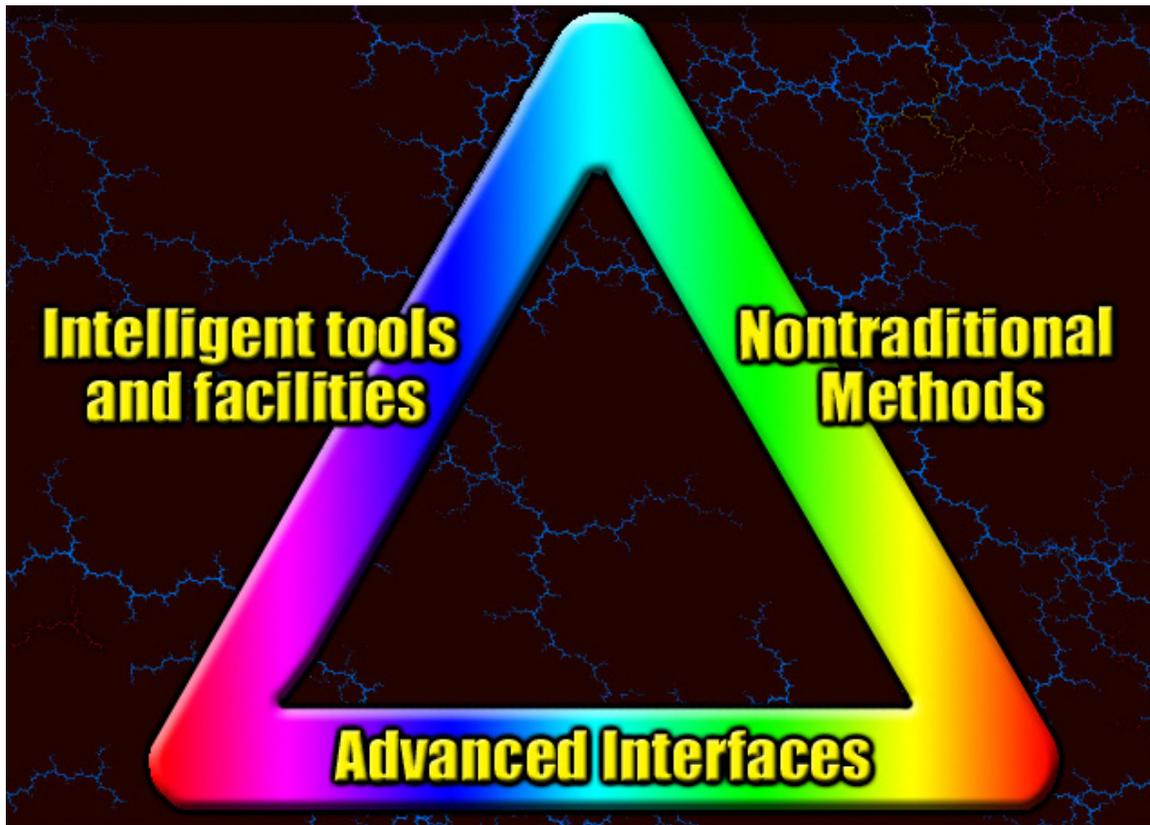


Figure 16

INTELLIGENT TOOLS AND FACILITIES

These include high fidelity – rapid modeling, simulation and interrogative visualization tools, synthetic immersive environments; close coupling of simulations and experiments; computer simulation of physical experiments and remote control of these experiments. In all of these tools, extensive use should be made of intelligent software agents and information technology (Figure 17).

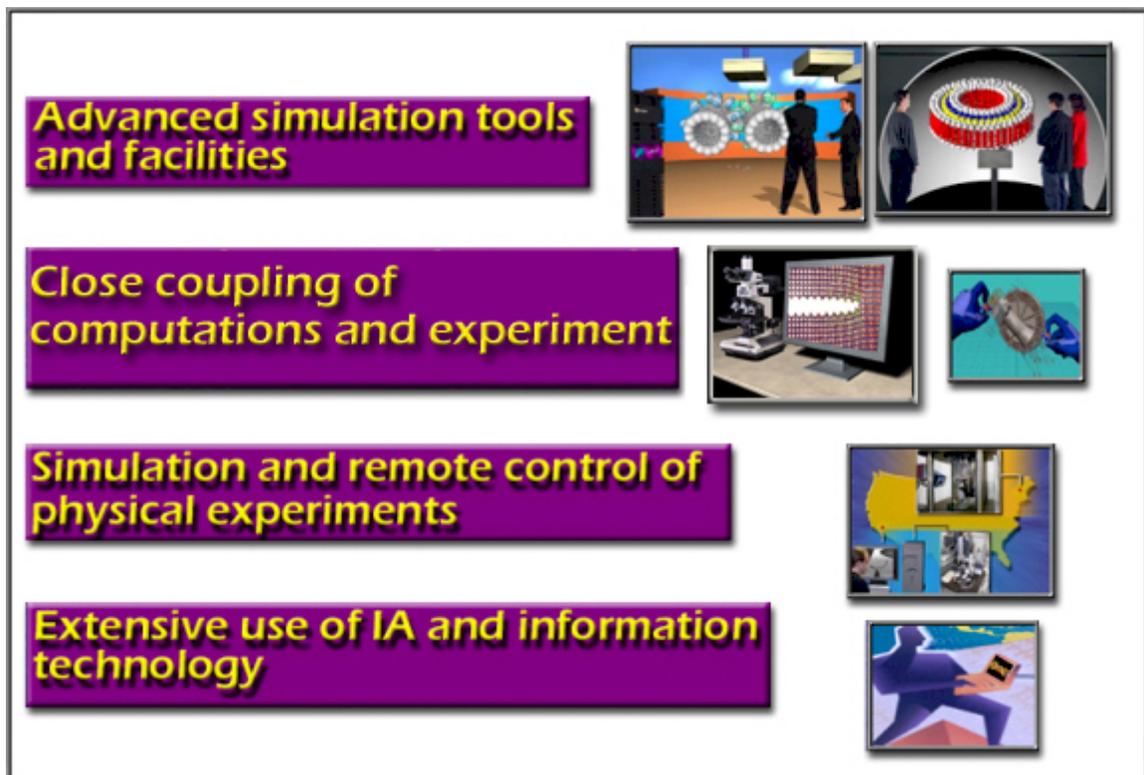


Figure 17

EXAMPLES OF FUTURE AEROSPACE SYSTEMS AND SOME OF THEIR CHARACTERISTICS

The realization of NASA's ambitious goals in aeronautics and space with the current national budget constraints will require new kinds of aerospace systems and missions that use novel technologies and manage risk in new ways. Future aerospace systems must be autonomous, evolvable, resilient, and highly distributed. Two examples are given in Figure 18. The first is a biologically inspired aircraft with self-healing wings that flex and react like living organisms. It is built of a multifunctional material with fully integrated sensing and actuation, and unprecedented levels of aerodynamic efficiencies and aircraft control. The second is an integrated human-robotic outpost, with biologically inspired robots. The robots could enhance the astronaut's capabilities to do large-scale mapping, detailed exploration of regions of interest, and automated sampling of rocks and soil. They could enhance the safety of the astronauts by alerting them to mistakes before they are made, and letting them know when they are showing signs of fatigue, even if they are not aware of it.

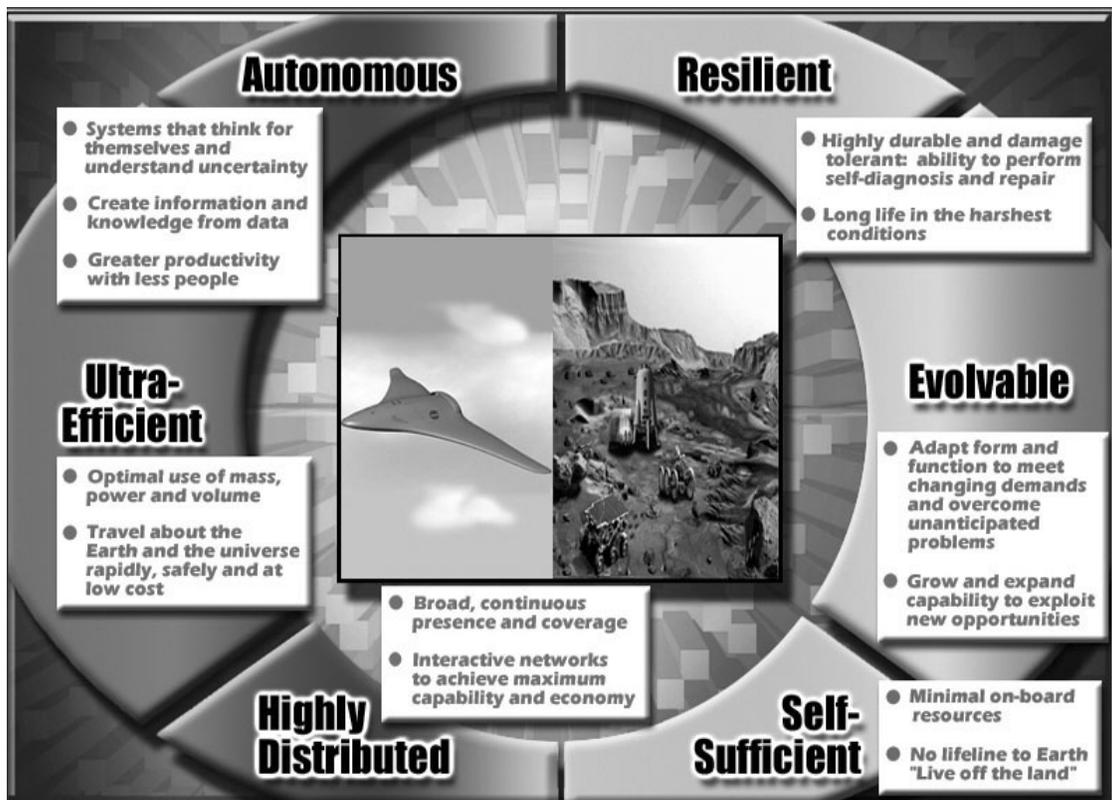


Figure 18

ENABLING TECHNOLOGIES FOR FUTURE AEROSPACE SYSTEMS

The characteristics of future aerospace systems identified in Figure 18 are highly coupled and require the synergistic coupling of the revolutionary and other leading-edge technologies listed in Figure 19. The four revolutionary technologies are: nanotechnology, biotechnology, information/knowledge technology, and cognitive systems technology. The other leading-edge technologies are high-productivity computing; high-capacity communication; multiscale modeling, simulation and visualization; virtual product development; intelligent software agents; reliability and risk management; human performance, and human-computer symbiosis.

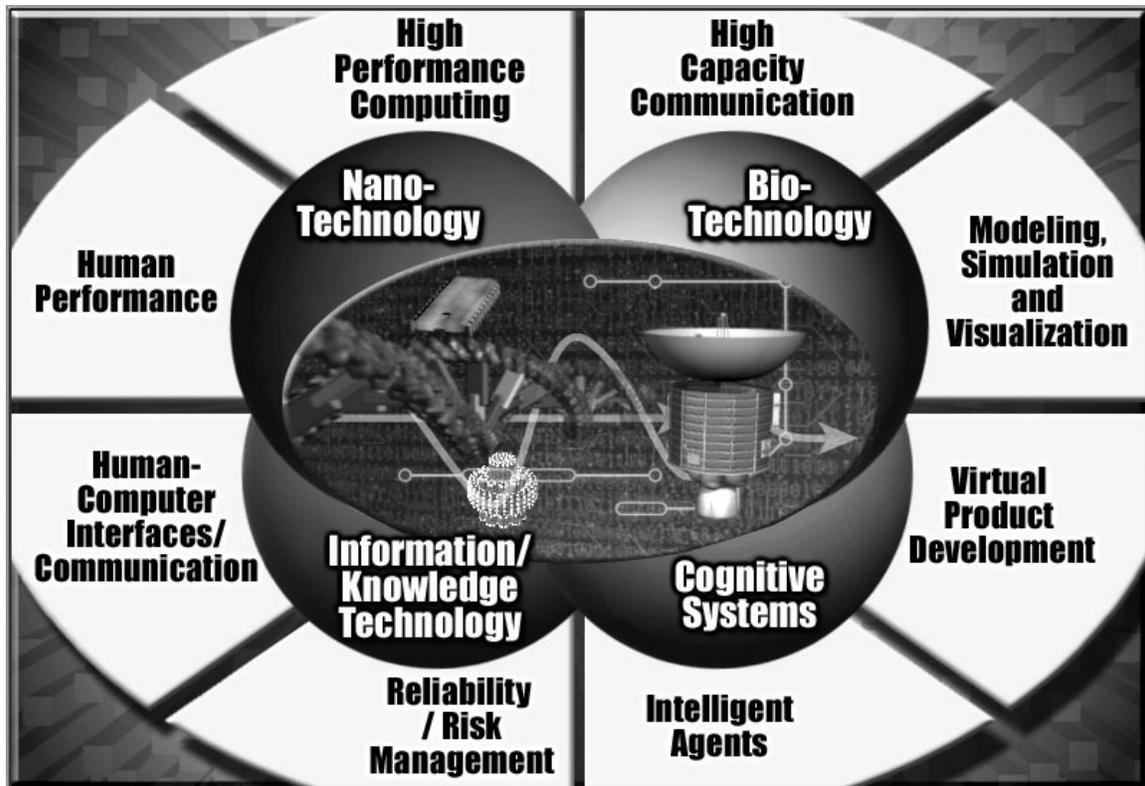


Figure 19

THREE NASA INITIATIVES

The realization of NASA's ambitious goals will require a diverse, technically skilled workforce – a new generation of scientists and engineers who can work across traditional disciplines and perform in a rapidly changing environment.

NASA has developed a number of new initiatives for assured workforce development. These include: University Research, Engineering, and Technology Institutes (URETIs), the National Institute of Aerospace (NIA), and the Hierarchical Research and Learning Network (HRLN) (see Figure 20). The overall goal of these activities is to strengthen NASA's ties to the academic community through long-term sustained investment in areas of innovative and long-term technology critical to future aerospace systems and missions. At the same time, the three activities will enhance and broaden the capability of the nation's universities to meet the needs of NASA's science and technology programs.

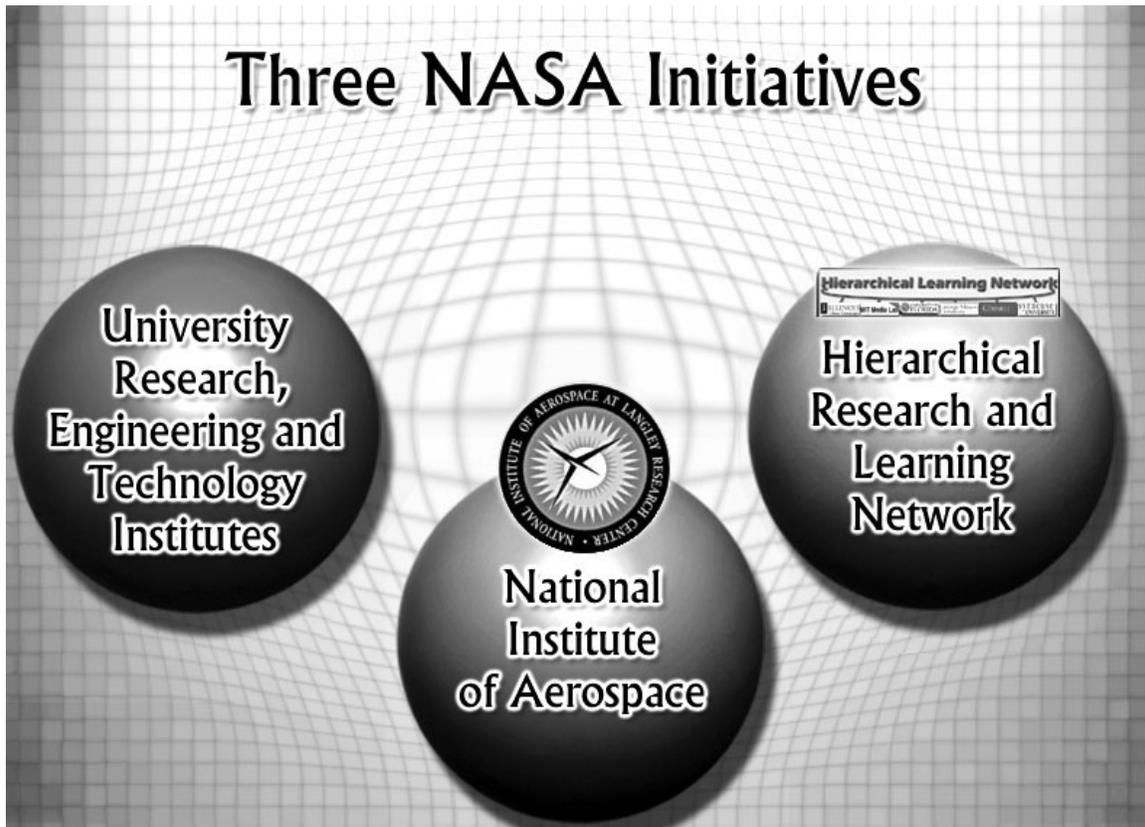


Figure 20

HIERARCHICAL RESEARCH AND LEARNING NETWORK

The Hierarchical Research and Learning Network (HRLN) is a pathfinder project for the future aerospace workforce development. It aims at creating knowledge organizations in revolutionary technology areas which enable collective intelligence, innovation and creativity to bear on the increasing complexity of future aerospace systems. This is accomplished by building research and learning networks linking diverse interdisciplinary teams from NASA and other government agencies with universities, industry, technology providers, and professional societies (Figure 21) in each of the revolutionary technology areas and integrating them into the HRLN.

HRLN is envisioned as a neural network of networks. It is being developed by eight university teams, led by Old Dominion University's Center for Advanced Engineering Environments.



Figure 21

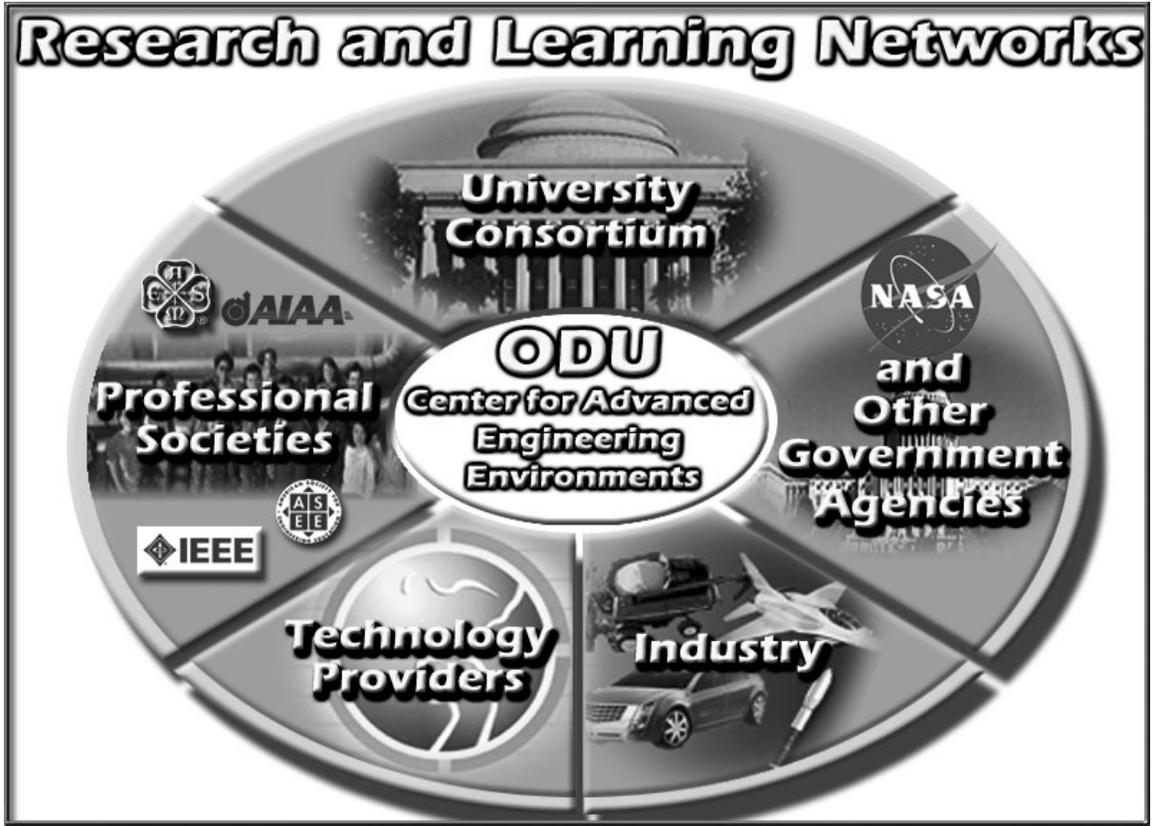


Figure 21 (continued)

IMPLEMENTAION OF HIERARCHICAL RESEARCH AND LEARNING NETWORK

The phases of implementing HRLN are shown in Figure 22. The first phase involves development of learning modules and interactive virtual classrooms in revolutionary technology areas, simulators of unique test facilities at NASA, and a telescience system – an online multi-site lab that allows real-time exchange of information and remote operation of instrumentation by geographically distributed teams. These facilities will be integrated into adaptive web learning portals in the second phase, which evolve into robust learning networks. In the final phase, the learning networks are integrated into the HRLN.

Implementation of Hierarchical Research and Learning Network

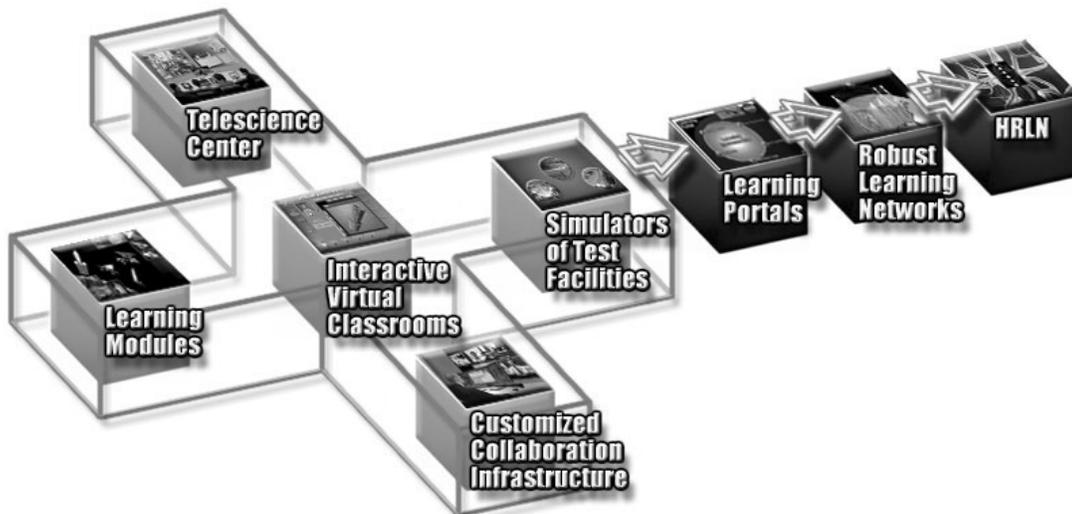


Figure 22

ADAPTIVE WEB LEARNING PORTAL

The Adaptive Web Learning Portal being developed as part of the HRLN project has the following major components (Figure 23):

- Advanced multimodal interfaces,
- Knowledge repository,
- Blended learning environment incorporating the three environments: expert-managed, self-paced, and collaborative,
- Learning management system, and
- Customized collaboration infrastructure

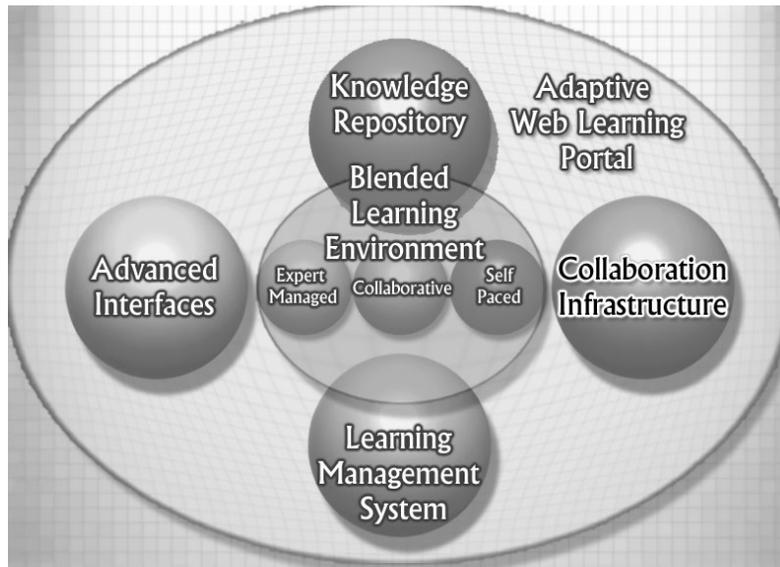


Figure 23

VIRTUAL CLASSROOM

Online training and virtual classrooms are typically used to provide learning environments with custom self-instruction, flexible tutorial support, and choice of both the place and time of learning. Three categories of facilities are used in these environments; namely: *instruction*, including multimedia lectures, links to other resources and tools for searching, browsing, and using archived knowledge; *communication*, including email, UseNet, chat centers, video and Internet conferencing; and *course management and performance evaluation* (Figure 24).

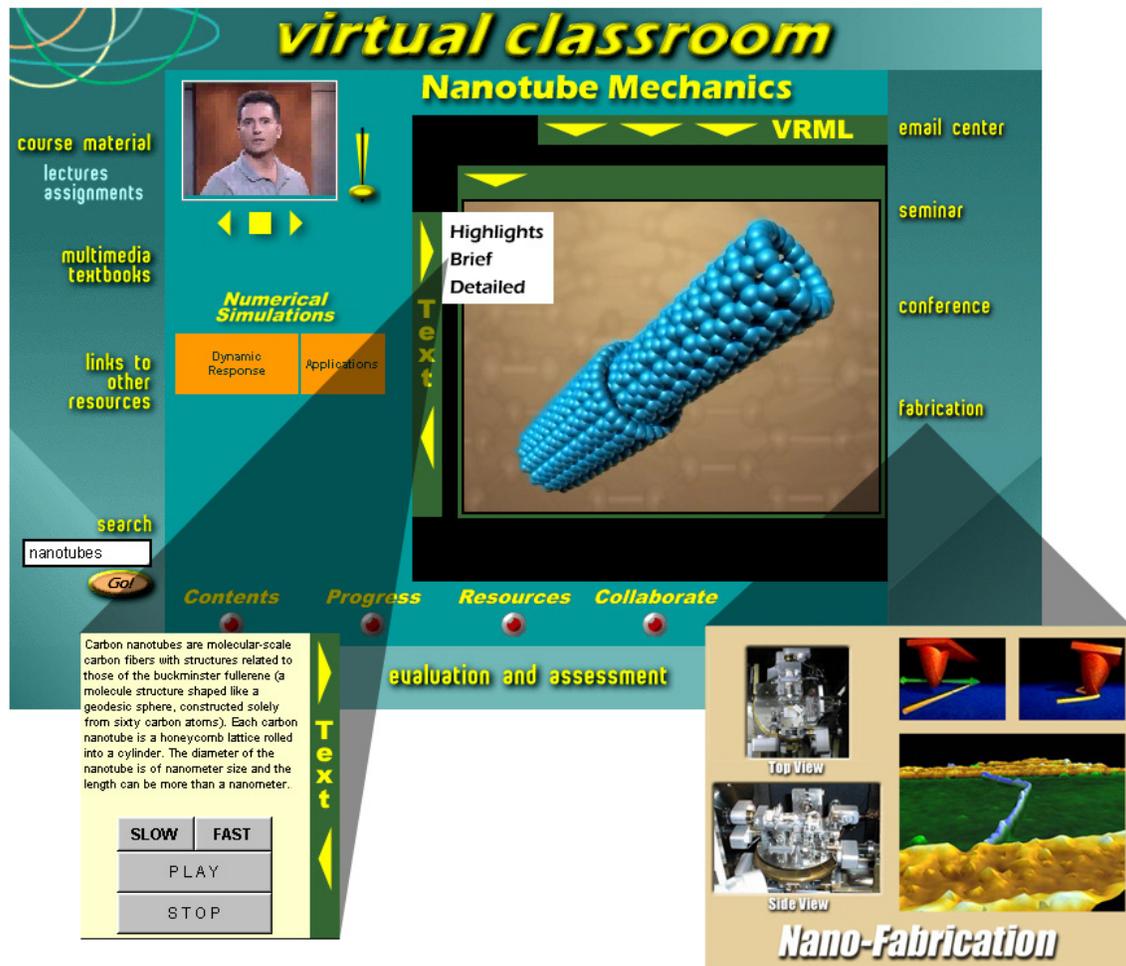


Figure 24

INTELLIGENT DESIGN ENVIRONMENT

The future design environment will enable collaborative distributed synthesis to be performed by geographically dispersed interdisciplinary/multidisciplinary teams. It will include flexible and dynamic roomware (active spaces/collaboration landscape) facilities consisting of (Figure 25):

- Portable and stationary information devices
- Novel multiuser smart displays
- Telepresence and other distributed collaboration facilities
- Novel forms of multimodal human/network interfaces
- Middleware infrastructures and intelligent software agents

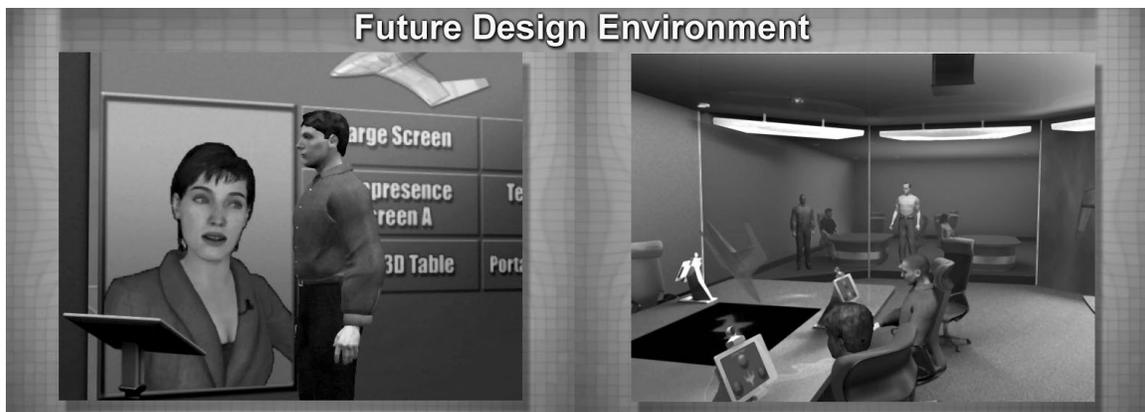


Figure 25

OBJECTIVES AND FORMAT OF WORKSHOP

The objectives of the workshop are to (Figure 26): a) provide broad overviews of the diverse activities related to advanced learning technologies and learning environments; and b) identify future directions for research that have high potential for future aerospace workforce development. The format included eighteen half-hour presentations in eight sessions.

- Objectives:
 - Overview of the diverse activities related to advanced learning technologies and learning environments
 - Identify future directions for research that have high potential for future aerospace workforce development

- *Format:*
 - 18 presentations; 8 sessions

- *Proceedings:*
 - NASA Conference Proceeding

Figure 26

INFORMATION ON ADVANCED LEARNING TECHNOLOGIES AND LEARNING ENVIRONMENTS

A short list of recent books, monographs, and reports on advanced learning technologies and learning environments is given subsequently.

- [1] “*Distributed Education: Summary of a Six-Part Series*”, American Council on Education, Washington, DC, 2003.
- [2] Levine, A. and Sun, J.C., “*Barriers to Distance Education*”, American Council on Education, Washington, DC, 2003.
- [3] Katz, R.N., “*WEB Portals and Higher Education: Technologies to make IT personal*”, EDUCAUSE, National Association of College and University Business Officers, San Francisco, CA, Jossey-Bass, 2002.
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- [17] Finkelstein, M.J., Frances, C., Jewett, F.I., Scholz, B.W., “*Dollars, Distance, and Online Education – The New Economics of College Teaching and Learning*”, Greenwood Publishing Group, Inc., Westport, CT, 2000.

